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# A Review on Steam Turbine Blade Desingand It's Principle

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## Abstract

Steam turbine is a prime mover that converts thermal energy in pressurized steam into useful mechanical work for its rotation. Turbine, in-turn, is used to power various rotating equipment like compressors, pumps, generators etc. A steam turbine is a rotary type of steam engine, having a rotating wheel to which is secured a series of buckets, blades or vanes, uniformly spaced on its periphery. Steam from nozzles or guide passages is directed continuously against these buckets, blades or vanes, thus causing their rotation. This paper will briefly describe steam turbine technology that can be adopted to provide onsite power generation. The feasibility of using a steam turbine will be evaluated for power generation industries. The Steam turbine can be used as an efficient mechanical device in the various power generation industries. also This paper will provide brief theory and the main types of steam turbines.
**Keywords: Steam Turbine, Blades, Impulse Turbine**

## I. INTRODUCTION

Turbines are the principal elements that convert the thermal energy into kinetic energy. It involves the thermodynamic, aerodynamic, mechanical and material science disciplines. The steam turbine is the simplest and most efficient engine for converting large amounts of heat energy into mechanical work. As the steam expands, it acquires high velocity and exerts force on the turbine blades. Turbines range in size from a few kilowatts for one stage units to 1300 MW for multiple-stage multiple-component units comprising high-pressure, intermediate-pressure, and up to three low-pressure turbines. For mechanical drives, Single and double-stage turbines are generally used. Larger modern turbines are multiple-stage axial flow units. The purpose of a steam turbine technology is to extract the maximum quantity of energy from the working fluid, to convert it into useful work with maximum efficiency, by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum starting time.

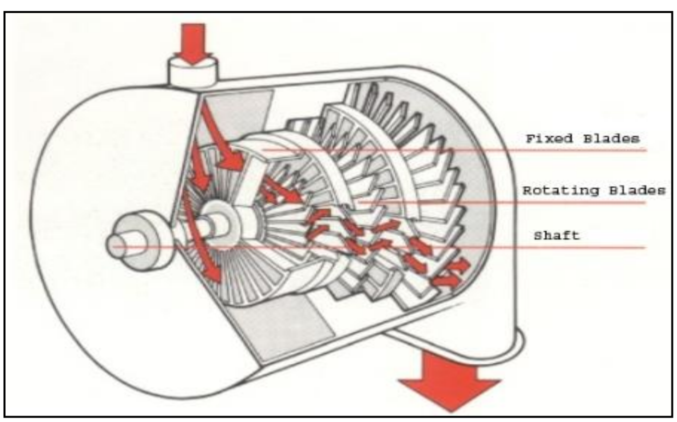

Fig. 1: Simple Steam Turbine

Steam turbines are used for a wide range of applications, including power generation, drivers for mechanical services. When coupled with gears they can be used to drive fans, reciprocating compressors and other classes of low-speed machinery. The largest turbine applications are generator drives in utility and other central power stations. Since steam can be generated with any type of fuel and in some cases, with recovered heat, steam energy can often be produced at a very low cost. Industrial steam turbines can potentially be applied with any high-pressure steam system and the result is low-to-moderate cost power generation with high reliability, low maintenance (when added to existing steam plants), and extremely long life.

## II. TYPES OF STEAM TURBINE

There Are The Main Two Types Of Steam Turbine (1) Impulse Turbine (2) Impulse Reaction Turbine

### *A. Turbine:*

The flow of steam through the nozzles and moving blades of a turbine takes place in such a manner that the steam is expanded only in nozzles and pressure at the outlet sides of the blades is equal to that at inlet side; such a turbine is termed as impulse turbine because it works on the principle of impulse. In other words, in impulse turbine, the drop in pressure of steam takes place only in nozzles and not in moving blades. This is obtained by making the blade passage of constant cross- section area. The law of momentum states that the sum of the moments of external forces acting on a fluid which is temporarily occupying the control volume is equal to the net time change of angular momentum flux through the control volume.

### *B. Impulse Reaction Turbine:*

In this turbine, the drop in pressure of steam takes place in fixed (nozzles) as well as moving blades. The pressure drop suffered by steam while passing through the moving blades causes a further generation of kinetic energy within the moving blades, giving rise to Reaction and adds to the propelling force which is applied through the rotor to the turbine shaft. Since this turbine works on the principle of impulse and reaction both, so it is called impulse-reaction turbine. This is achieved by making the blade passage of varying cross-sectional area (converging type).

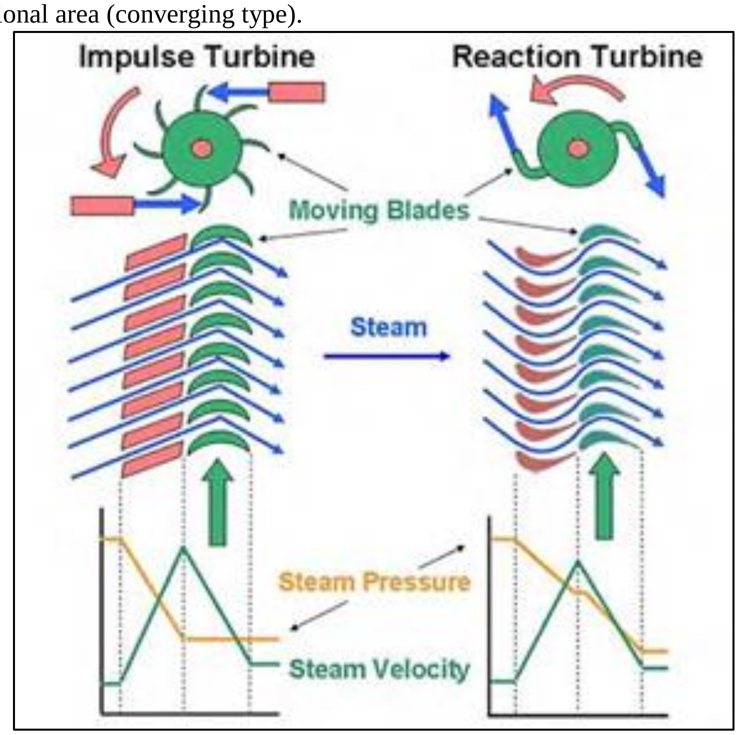


Fig. 2: Impulse Turbine and Impulse Reaction Turbine

## III. BLADE DESIGN OF STEAM TURBINE

### *A. Blade and Stage Design:*

Turbine blades are of two basic types, blades and nozzles. Blades move entirely due to the impact of steam on them and their profiles do not converge. This results in a steam velocity drop and essentially no pressure drop as steam moves through the blades. A turbine composed of blades alternating with fixed nozzles is called an impulse turbine, Curtis turbine, Rateau turbine, or Brown-Curtis turbine. Nozzles appear similar to blades, but their profiles converge near the exit. This results in a steam pressure drop and velocity increase as steam moves through the nozzles. Nozzles move due to both the impact of steam on them and the reaction due to the high-velocity steam at the exit. A turbine composed of moving nozzles alternating with fixed nozzles is called a reaction turbine or Parsons turbine. Except for low-power applications, turbine blades are arranged in multiple stages in series, called compounding, which greatly improves efficiency at low speeds. A reaction stage is a row of fixed nozzles followed by a row of moving nozzles. Multiple reaction stages divide the pressure drop between the steam inlet and exhaust into numerous small drops, resulting in a pressure-compounded turbine. Impulse stages may be either pressure-compounded, velocity-compounded, or pressure-velocity compounded. A pressure-compounded impulse stage is a row of fixed nozzles followed by a row of moving blades, with multiple stages for compounding. This is also known as a Rateau turbine, after its inventor.A velocity-compounded impulse stage (invented by Curtis and also called a "Curtis wheel") is a row of fixed nozzles followed by two or more rows of moving blades alternating with rows of fixed blades. This divides the velocity drop across the stage into several smaller drops. A series of velocity-compounded impulse stages is called a pressure-velocity compounded turbine.

Fig. 3: Selection Of Impulse Turbine Blades

### *B. Blade Design Challenges:*

A major challenge facing turbine design is reducing the creep experienced by the blades. Because of the high temperatures and high stresses of operation, steam turbine materials become damaged through these mechanisms. As temperatures are increased in an effort to improve turbine efficiency, creep becomes more significant. To limit creep, thermal coatings and super alloys with solid-solution strengthening and grain boundary strengthening are used in blade designs. Protective coatings are used in to reduce the thermal damage and to limit oxidation. These coatings are often stabilized zirconium dioxide-based ceramics. Using a thermal protective coating limits the temperature exposure of the nickel super alloy. This reduces the creep mechanisms experienced in the blade. Oxidation coatings limit efficiency losses caused by a buildup on the outside of the blades, which is especially important in the high-temperature environment.

## IV. PRINCIPLE OF STEAM TURBINE

An ideal steam turbine is considered to be an isentropic process, or constant entropy process, in which the entropy of the steam entering the turbine is equal to the entropy of the steam leaving the turbine. No steam turbine is truly isentropic, however, with typical isentropic efficiencies ranging from 20–90% based on the application of the turbine. The interior of a turbine comprises several sets of blades or buckets. One set of stationary blades is connected to the casing and one set of rotating blades is connected to the shaft. The sets intermesh with certain minimum clearances, with the size and configuration of sets varying to efficiently exploit the expansion of steam at each stage.

Fig. 4: Steam Turbine Fuelled With Biomass

## V. Operation and Maintenance of

A modern steam turbine generator installation. Because of the high pressures used in the steam circuits and the materials used, steam turbines and their casings have high thermal. When warming up a steam turbine for use, the main steam stop valves (after the boiler) have a bypass line to allow superheated steam to slowly bypass the valve and proceed to heat up the lines in the system along with the steam turbine. Also, a turning gear is engaged when there is no steam to slowly rotate the turbine to ensure even heating to prevent uneven expansion. After first rotating the turbine by the turning gear, allowing time for the rotor to assume a straight plane (no bowing), then the turning gear is disengaged and steam is admitted to the turbine, first to the astern blades then to the ahead blades slowly rotating the turbine at 10–15 RPM (0.17–0.25 Hz) to slowly warm the turbine. The warm up procedure for large steam turbines may exceed ten hours. During normal operation, rotor imbalance can lead to vibration, which, because of the high rotation velocities, could lead to a blade breaking away from the rotor and through the casing. To reduce this risk, considerable efforts are spent to balance the turbine. Also, turbines are run with high quality steam: either superheated (dry) steam, or saturated steam with a high dryness fraction. This prevents the rapid impingement and erosion of the blades which occurs when condensed water is blasted onto the blades (moisture carry over). Also, liquid water entering the blades may damage the thrust bearings for the turbine shaft. To prevent this, along with controls and baffles in the boilers to ensure high quality steam, condensate drains are installed in the steam piping leading to the turbine.

## VI. Steam Turbine Capacity and Capability

### *A. Capability:*

The capacities of small turbines and coupled generators vary from 500 to 7500 kW whereas large turbo alternators have capacity varying from 10 to 90 mW. Very large size units have capacities up to 500 mW. Generating units of 200 mW capacity are becoming quite common. The steam consumption by steam turbines depends upon steam pressure, and temperature at the inlet, exhaust pressure number of bleeding stages etc. The steam consumption of large steam turbines is about 3.5 to 5 kg per kWh.
Turbine kW = Generator kW / Generator efficiency Generators of larger size should be used because of the following reasons:

1) Higher efficiency.
2) Lower cost per unit capacity.
3) Lower space requirement per unit capacity. 3.45.1 Nominal rating. It is the declared power capacity of turbine expected to be maximum load.

### *B. Capability:*

The capability of steam turbine is the maximum continuous out put for a clean turbine operating under specified throttle and exhaust conditions with full extraction at any openings if provided. The difference between capability and rating is considered to be overload capacity. A common practice is to design a turbine for capability of 125% nominal rating and to provide a generator that will absorb rated power at 0.8 power factor. By raising power factor to unity the generator will absorb the full turbine capability.

## VII. Problem's and Their Root Causes

Steam turbine corrosion damage, particularly of blades and discs, has long been recognized as a leading cause of reduced availability It. has been estimated that turbine corrosion problems cost the U.S. utility industry as much as one billion dollars per year. When a corrosion problem is discovered during inspection or by equipment malfunction, the failure Mechanism and the root causes are not always known. Even when the damage fits a description of a well-known problem (disc or blade cracking), replacement parts may not be readily available and the decision for what to do has to be made quickly. The main objectives in handling identified and potential problems are maintaining safety. In the steam turbine the problems, their root causes are avoiding and most of them should be removed before operation.

### *A. Root Cause:*

Poor control of boiler operation (drum level) together with the use of the polymeric dispersant that, after evaporation of water, becomes a strong adhesive. Controls of the steam turbine allowed accidental disconnect.

### *B. Actions:*

New turbine installed, boiler and generator controls fixed, turbine valves reused after dissolution of the bushing deposits in hot water.

## VIII. CONCLUSION

Steam turbines can be a very reliable equipment with life over 30 years and overhaul approximately every 10 years. However, about 5 percent of the industrial and utility turbines Steam Turbines are one of the main energy consuming equipments, even though not much attention is paid to them. Trimming of operating parameters are essential for efficient operation of these turbines. Illustration given in the paper shows impact of operating conditions on steam turbines. Savings presented are for a typical operating conditions. Huge benefits can be reaped by optimizing operating parameters, by minor modifications and even by replacing old in-efficient turbines. It is important to note that a condensing turbine was not considered in the feasibility analysis simply because the capital cost and operating cost of the system would prove the feasibility uneconomical as the condenser would add additional capital and operational cost.

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